

New records of pyrenocarpous lichens from Jeju Island, South Korea

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ABSTRACT—Based on the morphological study of specimens collected from Jeju Island, ten pyrenocarpous lichen-forming fungi are reported for the first time from South Korea: *Agonimia globulifera*, *A. repleta*, *Anisomeridium japonicum*, *A. robustum*, *Anthracothecium macrosporum*, *Psoroglaena japonica*, *Strigula aquatica*, *Thelidium japonicum*, *T. pluvium*, and *T. radiatum*. Technical morphological descriptions and photographs of the Korean specimens are presented with the ecology and distribution for each species.

KEY WORDS—*Monoblastiaceae*, *Pyrenulaceae*, *Strigulaceae*, taxonomy, *Verrucariaceae*

Introduction

Pyrenocarpous lichens comprise a large number of species in tropical and subtropical areas, especially in freshwater and shaded habitats; despite their common and wide distribution, very little attention has been given to them. Several recent regional surveys have been conducted in Costa Rica (Aptroot & al. 2008), Europe (Coppins & Aptroot 2008, Orange 2008), Australia (McCarthy 2001), Japan (Harada 2001), and Korea (Moon & Aptroot

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2009), where many pyrenocarpous lichens species were recorded living on corticolous, foliicolous, and saxicolous substrates.

Although exploration of Korean lichen mycota has made considerable progress in recent years (Aptroot & Moon 2014; Hur & al. 2005; Kondratyuk & al. 2013, 2015, 2016a, b, 2017; Moon 2013), knowledge of the flora of pyrenocarpous lichen in these areas is far from complete. Our current research continues our investigation of Korean lichen mycota, chiefly in Jeju Island (southern coast of Korea); here we add information on ten pyrenocarpous lichens, all of which represent new records for South Korea.

Materials & methods

Specimens were collected from Jeju Island during 2014–15 and deposited in the herbarium of the Korean Lichen Research Institute, Suncheon, South Korea (KoLRI), now incorporated into the lichen herbarium of Korean National Arboretum, Pocheon, South Korea (KH). The morphology was examined with the aid of an Olympus SZX-7 stereomicroscope and an Olympus BX-50 compound microscope with DIC optics and photographed with a Canon 5D digital camera. Hand-sections were made by razor blade under a dissecting stereoscope, and mounted in water. All measurements were made in water, while 10% KOH was used for observing asci and ascospores in more detail.

Taxonomy

Agonimia globulifera M. Brand & Diederich, *Lejeunia* 162: 8 (1999)

Thallus green to dark greenish, small to medium size. Lobes irregular or cylindrical, 20–50 µm wide, aggregated into larger (0.02–0.05 mm), lobed squamules. Photobiont green alga. Sterile globules usually frequent, subspherical, black, shiny, superficial to ½ immersed, 70–200 µm diam., composed of pseudoparenchymatous cells; cells thin-walled, with an oil drop. Prothallus not distinct. Perithecia and pycnidia not seen in Korean specimen.

ECOLOGY & DISTRIBUTION—The Korean specimen was found growing over moss on shaded basalt boulders near a stream accompanied by *Fuscopannaria dissecta* and *Nephroma resupinatum*. *Agonimia globulifera* has been recorded from Europe, northern Asia, North America, and the subantarctic archipelago (Hafellner 2014, Sérusiaux & al. 1999); new to South Korea.

SPECIMEN EXAMINED—SOUTH KOREA. JEJU-DO, Seogwipo-si, Halla Mountains, Eorimok Trail, 33°23'05"N 126°30'00"E, 1067 m asl, on moss over rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151692 (KoLRI 035385).

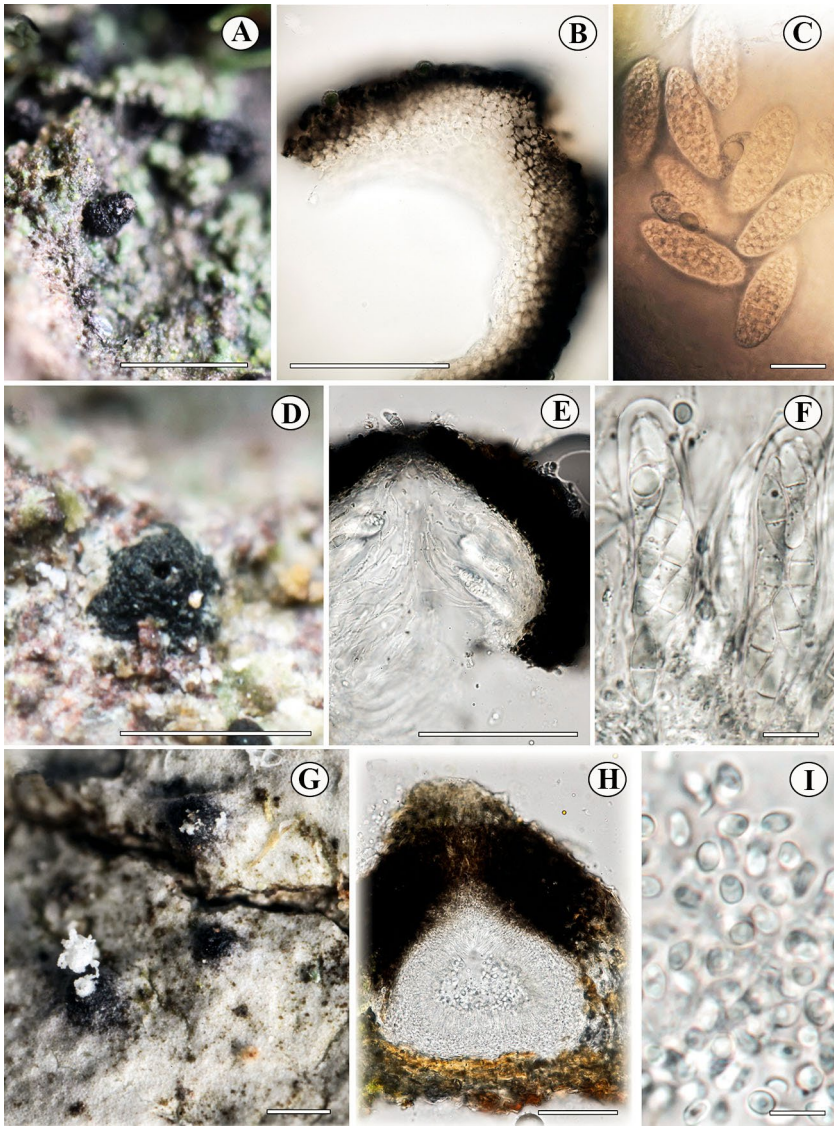


PLATE 1. Pyrenocarpous lichens from South Korea: *Agonimia repleta* (KoLRI 035254), A. thallus with ascomata; B. ascoma, vertical section; C. ascospores. *Anisomeridium japonicum* (KoLRI 035220), D. thallus with ascomata; E. ascoma, vertical section; F. ascospores. *Anisomeridium robustum* (KoLRI 035252), G. thallus with pycnidia; H. pycnidium, vertical section; I. pycnosporos. Scale bars: A, D, G = 500 μ m; B, E, H = 100 μ m; C = 20 μ m; F, I = 10 μ m.

COMMENTS—The Korean specimen agrees with the description by Sérusiaux & al. (1999), but perithecia and pycnidia were not seen in the Korean material. *Agonimia globulifera* is similar to *A. koreana*, a species previously reported from South Korea distinguished by its larger squamules (0.2–0.4 mm; Kashiwadani 2008).

Agonimia repleta Czarnota & Coppins, *Graphis Scripta*, 11: 56 (2000) PL. 1A–C

Thallus dull green, granular to verrucose or minutely squamulose; granules 30–120 μm diam.; squamules elongate if present, $240 \times 100 \mu\text{m}$. Photobiont green alga, 8–10 μm diam. Perithecia black, slightly immersed amongst thalline granules, 160–200 μm diam., globose when young but soon becoming pyriform, with a neck roughened by vertical channels. Ostiole brown to black. Asci clavate, 8-spored. Ascospores hyaline, globose or ellipsoid, muriform, $20\text{--}40 \times 12\text{--}20 \mu\text{m}$. Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean specimen was found living on a mossy rock near a stream in deep shade accompanied by *Porpidia albocaerulescens* at the collection site. *Agonimia repleta* is known from Europe, northern Asia, North America, and the subantarctic archipelago (Hafellner 2014); new to South Korea.

SPECIMEN EXAMINED—SOUTH KOREA. JEJU-DO, Jeju-si, Halla Mts, Arail-dong, trail to Gwaneum Temple, $33^{\circ}25'12''\text{N}$ $126^{\circ}32'56''\text{E}$, 601 m asl, on rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151561 (KoLRI 035254).

COMMENTS—The Korean specimen agrees with the description of *Agonimia repleta* by Czarnota & Coppins (2000). The species resembles *A. tristicula* in producing pyriform perithecia with a longitudinally furrowed (plicate) necks, but *A. tristicula* is distinguished by 2-spored asci and much larger ascospores ($57\text{--}120 \times 26\text{--}50 \mu\text{m}$; Orange 2008). *Agonimia repleta* also resembles *A. allobata* and *A. octospora*, both of which differ by their pale or pinkish ostiolar area (Orange 2008).

Anisomeridium japonicum H. Harada, *Nat. Hist. Res.* 5(2): 53 (1999) PL. 1D–F

Saxicolous. Thallus crustose, continuous, greenish gray, thin, smooth. Hypothallus and margin not distinct. Photobiont *Trentepohlia*. Perithecia hemispherical, dark brown or almost black, rather abruptly delimited at base, with rounded apices, 150–200 μm diam.; ostioles apical, inconspicuous. Involucrellum extending to the exciple base, ca. 25 μm thick in the upper part, dark purplish brown. Exciple colourless, 10–15 μm thick. Pseudoparaphyses branched and anastomosing to form a network. Asci clavate, $40 \times 10 \mu\text{m}$. Ascospores hyaline, ellipsoidal to oval, 1-septate, with rounded apices, lacking episore, $9\text{--}16 \times 4\text{--}6 \mu\text{m}$. Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean specimens were found on mossy rocks near a stream under very shaded conditions accompanied by *Pilophorus clavatus* and *Thelidium japonicum* in the Halla Mountains. Our collections extend the range of *Anisomeridium japonicum* from Japan (Harada 1999) to South Korea.

SPECIMENS EXAMINED—**SOUTH KOREA. JEJU-DO:** Jeju-si, Halla Mts, Arail-dong, trail to Gwaneum Temple, 33°24'03"N 126°32'25"E, 868 m asl, on rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151525 (KoLRI 035218), 151526 (KoLRI 035219), 151527 (KoLRI 035220).

COMMENTS—The Korean specimens found growing on non-calcareous rocks in a semi-freshwater habitat agree with the type description in Harada (1999). *Anisomeridium japonicum* is similar to *A. carinthiacum* and *A. distans*, but the ascospores are larger (13–18 × 5.5–7 µm) in *A. carinthiacum* has larger ascospores and 3-septate in *A. distans* (Harris 1995).

Anisomeridium robustum Orange, Coppins & Aptroot,
Lichenologist 40: 363 (2008)

PL. 1G–I

Corticolous. Thallus thin, white or pale greyish, often cracked. Photobiont *Trentepohlia*. Pycnidia black, 180–320 µm diam., 150–250 µm high, with a globose or conical base tapering into a narrow, <1.5 mm long neck. Conidia hyaline, simple, pyriform to ellipsoid, with truncate base, 2.5–4 × 2–3 µm.

ECOLOGY & DISTRIBUTION—The Korean specimens were found growing on the bark in more or less humid conditions associated with *Agonimia pacifica*. Our collections extend the range of *Anisomeridium robustum* from Europe (Coppins & Aptroot 2008) to South Korea.

SPECIMENS EXAMINED—**SOUTH KOREA. JEJU-DO:** Jeju-si, Halla Mts, Arail-dong, trail to Gwaneum Temple, 33°24'03"N 126°32'25"E, 868 m asl, on bark, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151559 (KoLRI 035252); **Seogwipo-si**, Halla Mts, Yeongsil Trail, 33°21'16"N 126°29'58"E, 1337 m asl, on bark, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151565 (KoLRI 035258).

COMMENTS—The morphology of the Korean specimens agrees with the description of Coppins & Aptroot (2008) and represents a new record of *Anisomeridium robustum* not only for Korea, but also for Asia. The species is distinguished from the similar *A. polypori* by its much larger macropycnidia and conidia (Orange 2008).

Anthracotheций macrosporum (Hepp) Müll. Arg., Linnaea 43: 44 (1880) PL. 2A–C

Corticolous. Thallus crustose, yellow to green, 10–30 cm diam., smooth, thick. Photobiont *Trentepohlia*. Perithecia prominent, hemispherical, usually

covered by thallus, yellowish brown to black, 1–1.5 mm diam. Ostiole brown. Involucrellum extending to the base, brownish black, 100–160 µm thick. Paraphyses simple to rarely branched or sparsely anastomosed, 1.5–2 µm diam. Asci clavate, bitunicate, 2-spored. Spores brown, oblong, with 10–15 transverse septa, 12–20-celled, 125–200 × 30–45 µm.

ECOLOGY & DISTRIBUTION—The Korean material was found living on bark associated with *Anisomeridium robustum*, *Bacidina chlorotricula*, and *Graphis anfractuosa*. *Anthracotheций macrosporum*, with pantropical distribution (Aptroot 2011), is new to South Korea.

SPECIMENS EXAMINED—SOUTH KOREA. JEJU-DO, Jeju-si, Halla Mts, Arail-dong, trail to Gwaneum Temple, 33°24'03"N 126°32'25"E, 868 m asl, on bark, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151544 (KoLRI 035237); 33°25'12"N 126°32'56"E, 601 m asl, on bark, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151579 (KoLRI 035272).

COMMENTS—*Anthracotheций macrosporum* is characterized by a thick greenish thallus, large perithecia, thick involucrellum, apical ostiole, euseptate 2-spored asci, and large ascospores. *Anthracotheций prasinum* and *A. gregale* are close to *A. macrosporum* but can be distinguished by having 4–6-ascospores per ascus (Aptroot 2011).

Psoroglaena japonica H. Harada, Lichenology 2: 5 (2003)

PL. 2D–F

Saxicolous. Thallus crustose, farinose, spreading, green to dark green, 10 mm diam. Photobiont green alga. Perithecia immersed into rocks at base, hemispherical, ellipsoidal, or pyriform, pale orangish brown to dark brown, 0.2–0.4 mm diam. Exciple hyaline internal, orangish brown or brown in the outer layer. Paraphyses hyaline, without prominently pointed or rounded apices, 20–25 µm long, 1–1.5 µm thick. Ascus clavate, 8-pored, 60–80 × 10 µm. Ascospores oval, hyaline, 13–17 × 5–6 µm, 3-septate. Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean material was found growing on basalt rock accompanied by *Agonimia pacifica*, *Fuscopannaria dissecta*, *Graphis anfractuosa*, and *Pilophorus clavatus*. Our collection extends the range of *Psoroglaena japonica* from Japan (Harada 2003) to South Korea.

SPECIMEN EXAMINED—SOUTH KOREA. JEJU-DO, Seogwipo-si, Halla Mts, Yeongsil Trail, 33°21'12"N 126°29'52"E, 1308 m asl, on rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151671 (KoLRI 035364).

COMMENTS—The Korean specimen matches the type description by Harada (2003). *Psoroglaena japonica* is most similar to *P. stigonemoides*, which differs by its filamentous to granular thallus with papillose cortical cells, its pale perithecia, its 3–5-septate ascospores, and its corticolous habit (Orange 1989). Epiphytic *P. cubensis* resembles *P. japonica* but differs in forming a

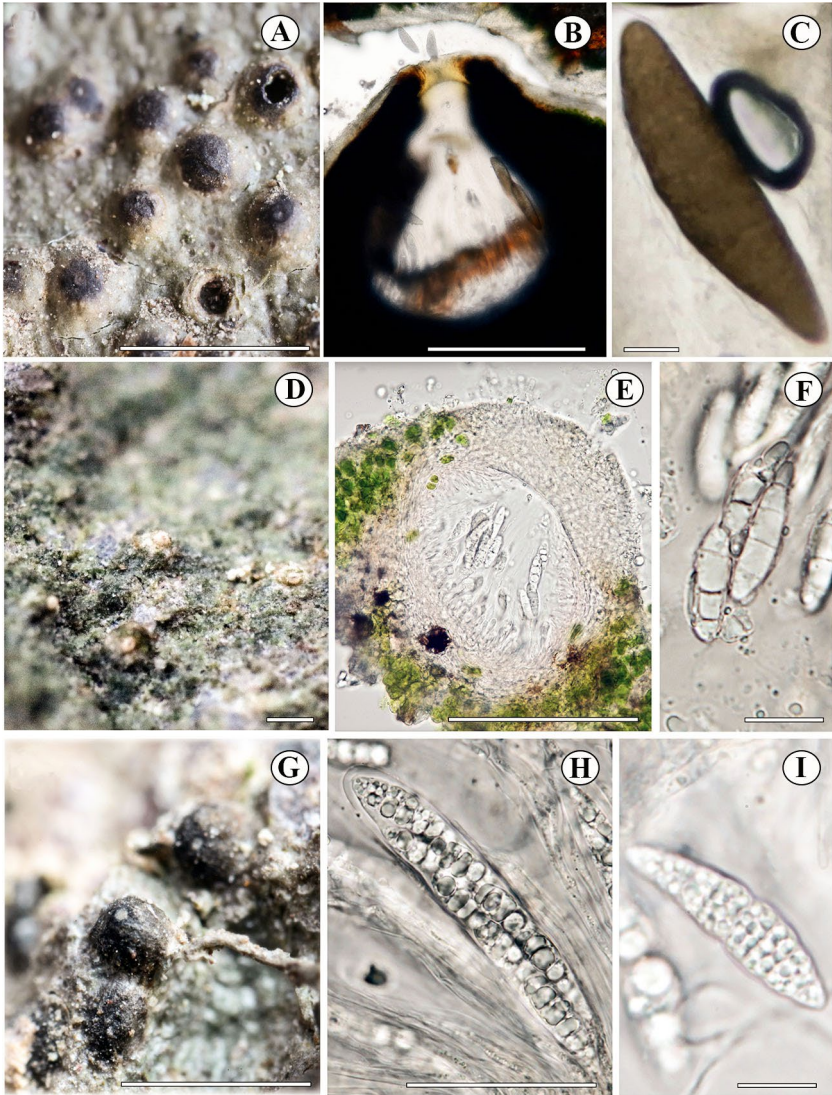


PLATE 2. Pyrenocarpous lichens from South Korea: *Anthracothecium macrosporum* (KoLRI 035272), A. thallus with ascomata; B. ascoma, vertical section; C. ascospores. *Psoroglaena japonica* (KoLRI 035364), D. thallus with ascomata; E. ascoma, vertical section; F. ascospores. *Strigula aquatica* (KoLRI 035221), G. thallus with ascomata; H. ascus with ascospores; I. ascospore. Scale bars: A = 3 mm; B, D, E = 100 μ m; C, F, I = 10 μ m; G = 500 μ m; H = 50 μ m.

finely lobate thallus (Eriksson 1992). Two other close species, *P. perminuta* and *Phylloblastia borhidii*, are foliicolous species and known only from Africa (McCarthy & Kantvilas 2013).

Strigula aquatica H. Harada, Nova Hedwigia 66: 420 (1998)

PL. 2G-I

Saxicolous. Thallus continuous, thin, grey; hypothallus filmy, whitish. Perithecia, hemispherical, dark brown to black near the apex, papillate at the apical ostiole or round at the top, widely pyriform, $190\text{--}260 \times 240\text{--}330\text{ }\mu\text{m}$. Photobiont *Trentepohlia*. Involucrellum dark brown. Exciple brown in the upper part, hyaline in lower part. Periphyses indistinct, simple, hyaline. Paraphyses unbranched, septate, $1.5\text{ }\mu\text{m}$ thick. Asci cylindrical, 8-spored, $75 \times 15\text{ }\mu\text{m}$. Spores fusiform, hyaline, 7-septate, thin-walled, slightly constricted in the middle, $26\text{--}30 \times 6\text{--}7\text{ }\mu\text{m}$. Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean material was found growing on basalt stones in the banks of a brook associated with *Agonimia pacifica* and *Pilophorus clavatus*. Our collections extend the range of *Strigula aquatica* from Japan (Harada 1998) to South Korea.

SPECIMENS EXAMINED—SOUTH KOREA. JEJU-DO, Jeju-si, Halla Mts, Arail-dong, trail to Gwaneum Temple, $33^{\circ}24'03''\text{N}$ $126^{\circ}32'25''\text{E}$, 868 m asl, on rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151528 (KoLRI 035221), 151529 (KoLRI 035222), 151531 (KoLRI 035224).

COMMENTS—*Strigula aquatica* is characterized by its continuous pale greenish-gray thallus, scattered dome shaped perithecia, non-carbonized involucrellum, and 7-septate fusiform hyaline ascospores. Contrasted with other similar saxicolous *Strigula* species, *S. nipponica* differs in having a carbonized involucrellum, while *S. confusa* and *S. rupestris* are distinguished by muriform ascospores (Harada 2016, McCarthy 1997, Orange 2008).

Thelidium japonicum H. Harada, Nat. His. Res. 1(2): 9 (1991)

PL. 3A-C

Saxicolous. Thallus distinct or inconspicuous, green or greenish brown, granulose to areolate. Phycobiont cells isodiametric. Hypothallus black, gelatinous, not distinct. Perithecia abundant, hemispherical, $100\text{--}200\text{ }\mu\text{m}$ diam., with a very dark brown to black wall; ostiolar part pale to dark brown. Involucrellum inconspicuous or absent. Exciple colorless. Asci clavate, 8-spored, $85 \times 25\text{ }\mu\text{m}$, bitunicate. Spores hyaline, thin-walled, 1-septate, $17\text{--}26 \times 8\text{--}12\text{ }\mu\text{m}$. Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean specimens were found growing on basalt rocks together with *Agonimia pacifica*, *Anisomeridium japonicum*,

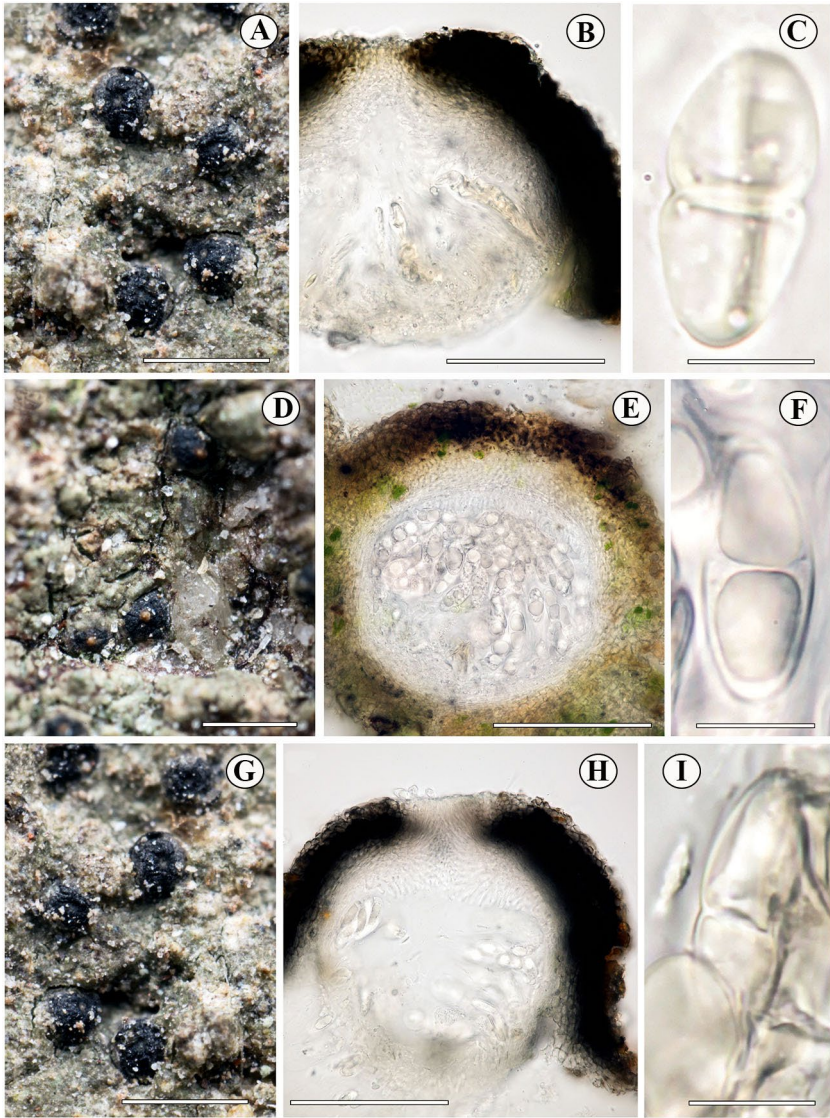


PLATE 1. Pyrenocarpous lichens from South Korea: *Thelidium japonicum* (KoLRI 035223), A. thallus with ascomata; B. ascoma, vertical section; C. ascospores. *Thelidium pluvium* (KoLRI 035267), D. thallus with ascomata; E. ascoma, vertical section; F. ascospores. *Thelidium radiatum* (KoLRI 035288), G. thallus with ascomata; H. ascoma, vertical section; I. ascospores. Scale bars: A, D, G = 500 µm; B, E, H = 100 µm; C, F, I = 10 µm.

and *Pilophorus clavatus*. Our collections extend the range of *Thelidium japonicum* from Japan (Harada 1991) to South Korea.

SPECIMENS EXAMINED—SOUTH KOREA. JEJU-DO, Jeju-si, Halla Mts, Arail-dong, trail to Gwaneum Temple, 33°24'03"N 126°32'25"E, 868 m asl, on rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151530 (KoLRI 035223), 151533 (KoLRI 035226), 151545 (KoLRI 035238), 151550 (KoLRI 035243), 151553 (KoLRI 035246), 151554 (KoLRI 035247).

COMMENTS—The Korean specimens agree with the type description by Harada (1991). *Thelidium japonicum* is most similar to *T. minutulum*, which differs by its grey-brown perithecial walls (Körber 1863) and its larger perithecia, absence of an involucrellum and more or less brownish exciple (Orange 2008).

Thelidium pluvium Orange, Lichenologist 23: 101 (1991)

PL. 3D–F

Saxicolous. Thallus slightly rimose, pale grey-green to dark brown, 35–85 µm thick. Photobiont green alga. Perithecia hemispherical, black, 220–400 µm diam.; ostiole conspicuous, prominent, not in a depression. Involucrellum rather thin, brown, K– or K + darker brown or greenish brown. Periphyses sparsely branched, 40 × 2–3 µm. Asci clavate, 8-spored, 75–100 × 25–30 µm. Ascospores ellipsoid, smooth, colourless, 1-septate, 23–36 × 9–16 µm, with numerous oily droplets when mature. Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean material was found growing on basalt rocks associated with *Pilophorus clavatus*, and *Verrucaria margacea*. *Thelidium pluvium* occurs on siliceous and slightly basic rocks in streambeds and on dripping rocks in Europe, Asia, and Australia (Orange 1991, 2008); new to South Korea.

SPECIMEN EXAMINED—SOUTH KOREA. JEJU-DO, Seogwipo-si, Halla Mts, Yeongsil Trail, 33°21'16"N 126°29'58"E, 1337 m asl, on rock, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151574 (KoLRI 035267).

COMMENTS—The Korean specimen agrees with the type description by Orange (1991). *Thelidium pluvium* is characterized by rather large perithecia covered by a layer of thallus except at dark apex, hyaline perithecial wall, and hyaline 1-septated ascospores. The otherwise similar *Thelidium pyrenophorum* and *T. methorium* differ in having a thick involucrellum and lacking a thalline cover on mature perithecia (Orange 2008).

Thelidium radiatum H. Harada, Hikobia 12: 133 (1996)

PL. 3G–I

Saxicolous. Thallus crustose, continuous, smooth, grayish green, margin not distinct. Perithecia black, hemispherical, 200–300 µm diam., without a

thalline cover, $\pm$ with cracks radiating around prominently depressed ostioles. Involucrellum appressed to exciple, $\pm$ extending to the perithecial base, 220–300 μm diam., 15–30 μm thick, dark brown to black. Exciple hyaline, 5–10 μm thick at base. Hymenium globose to depressed ovate, 100–200 $\times$ 140–230 μm . Upper periphyses simple, lower periphyses very sparsely branched, both 30–45 μm long. Asci clavate, 8-spored, 75 $\times$ 20 μm . Spores hyaline, oval, 1-septate, 22–27 $\times$ 8–11 μm . Pycnidia not seen.

ECOLOGY & DISTRIBUTION—The Korean specimens were found growing on basalt rocks associated with *Agonimia pacifica*, *Pilophorus clavatus*, and *Verrucaria margacea*. Our collections extend the range of *Thelidium radiatum* from Japan (Harada 1996) to South Korea.

SPECIMENS EXAMINED—**SOUTH KOREA.** JEJU-DO: Jeju-si, Arail-dong, trail to Gwaneum Temple, 33°24'03"N 126°32'25"E, 868 m asl, on rock, 21 Jul. 2015, J.P. Halda, S. O.-Oh & D. Liu 151535 (KoLRI 035228), 151552 (KoLRI 035245); Seogwipo-si, Halla Mt., Yeongsil Trail, 33°21'19"N 126°29'59"E, 1353 m asl, 21 Jul. 2015, J.P. Halda, S.-O. Oh & D. Liu 151595 (KoLRI 035288).

COMMENTS—The Korean material of *Thelidium radiatum* matches the type description by Harada (1996). The similar *T. japonicum* and *T. minutulum* are distinguished by their small perithecia that are dark brown to black at the base of perithecial walls and with projecting whitish ostioles, shorter ascospores, and the absence of an involucrellum. *Thelidium japonicum* is further distinguished from *T. radiatum* by forming granulose to areolate thallus. (Harada 1991).

Discussion

Moon (2013) confirmed 57 pyrenocarpous lichens from Korea, one third of which represented *Verrucaria* with boreal or cosmopolitan distribution. The largest (ca. 20%) percentage of *Verrucaria* recently reported from Korea is characterized by East Asian distribution. Islands between Korea and Japan represent important localities for lichens previously known only from type localities in Japan. Some species (e.g., *Verrucaria miyagiensis*) are in urgent need of serious taxonomic revision to establish their modern taxonomic relationships. Some East Asian representatives were described mainly from Japan (e.g., *Strigula maritima*, *Thelidium izuense*; Harada 2013, 2016) and China (*Thelidium yunnanum*; Harada & Wang 2004). The addition of an inconspicuous new species, *Thelenella haradae* from South Korea (Halda & Hur 2016) also illustrates that a number of pyrenocarpous lichens are still overlooked.

Acknowledgments

We thank Santosh Joshi (CSIR-National Botanical Research Institute, Lucknow, India) and László Lőkös (Hungarian Natural History Museum, Budapest) for their attentive and insightful corrections and suggestions. This work was supported by a grant from the Korean Forest Service Program (KNA1-1-14, 14-2) through Korean National Arboretum and the Korea National Research Resource Center Program (NRF-2017M3A9B8069471).

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